DART: Double Asteroid Redirection Test

NASA's First Planetary Defense Test Mission

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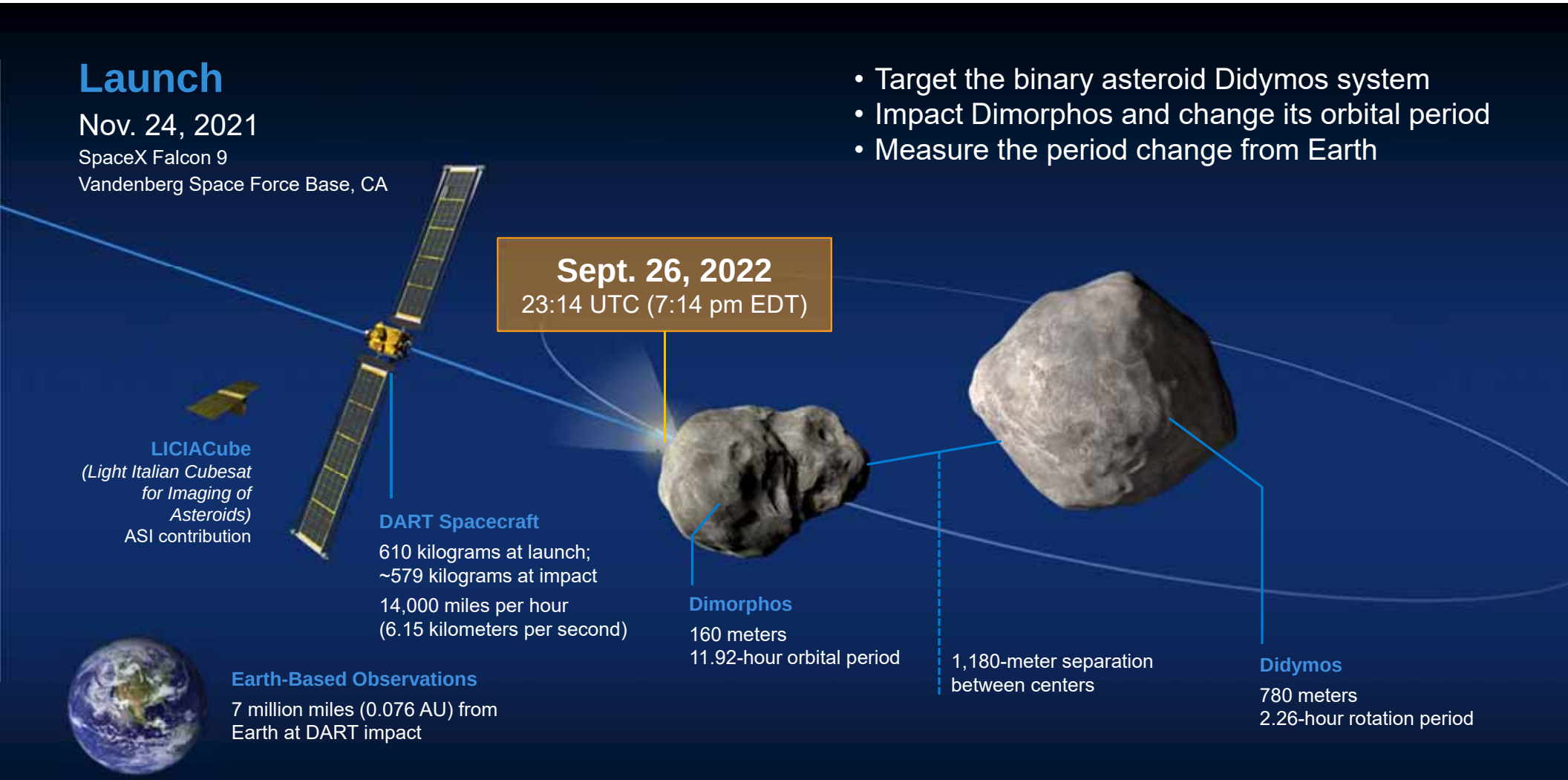
Launch

Nov. 24, 2021

SpaceX Falcon 9

Vandenberg Space Force Base, CA

- Target the binary asteroid Didymos system
- Impact Dimorphos and change its orbital period
- Measure the period change from Earth



Sept. 26, 2022
23:14 UTC (7:14 pm EDT)

LICIACube
(Light Italian Cubesat for Imaging of Asteroids)
ASI contribution

DART Spacecraft
610 kilograms at launch;
~579 kilograms at impact
14,000 miles per hour
(6.15 kilometers per second)

Dimorphos
160 meters
11.92-hour orbital period

1,180-meter separation between centers

Didymos
780 meters
2.26-hour rotation period

Earth-Based Observations
7 million miles (0.076 AU) from Earth at DART impact

DART Requirements

1

Impact Dimorphos

During its Sept/Oct 2022 close approach to Earth

2

Change the binary orbital period

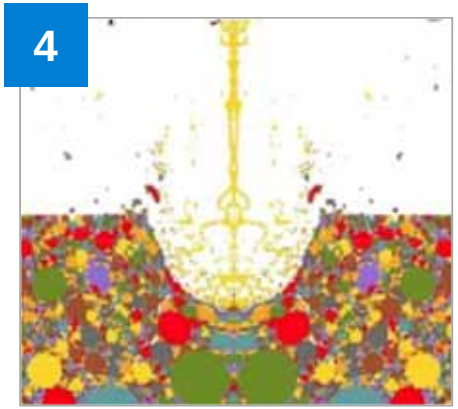
Cause a ≥73-second change in the orbital period of Dimorphos

3

Measure the period change

To within 7.3 seconds, from ground-based observations before and after impact

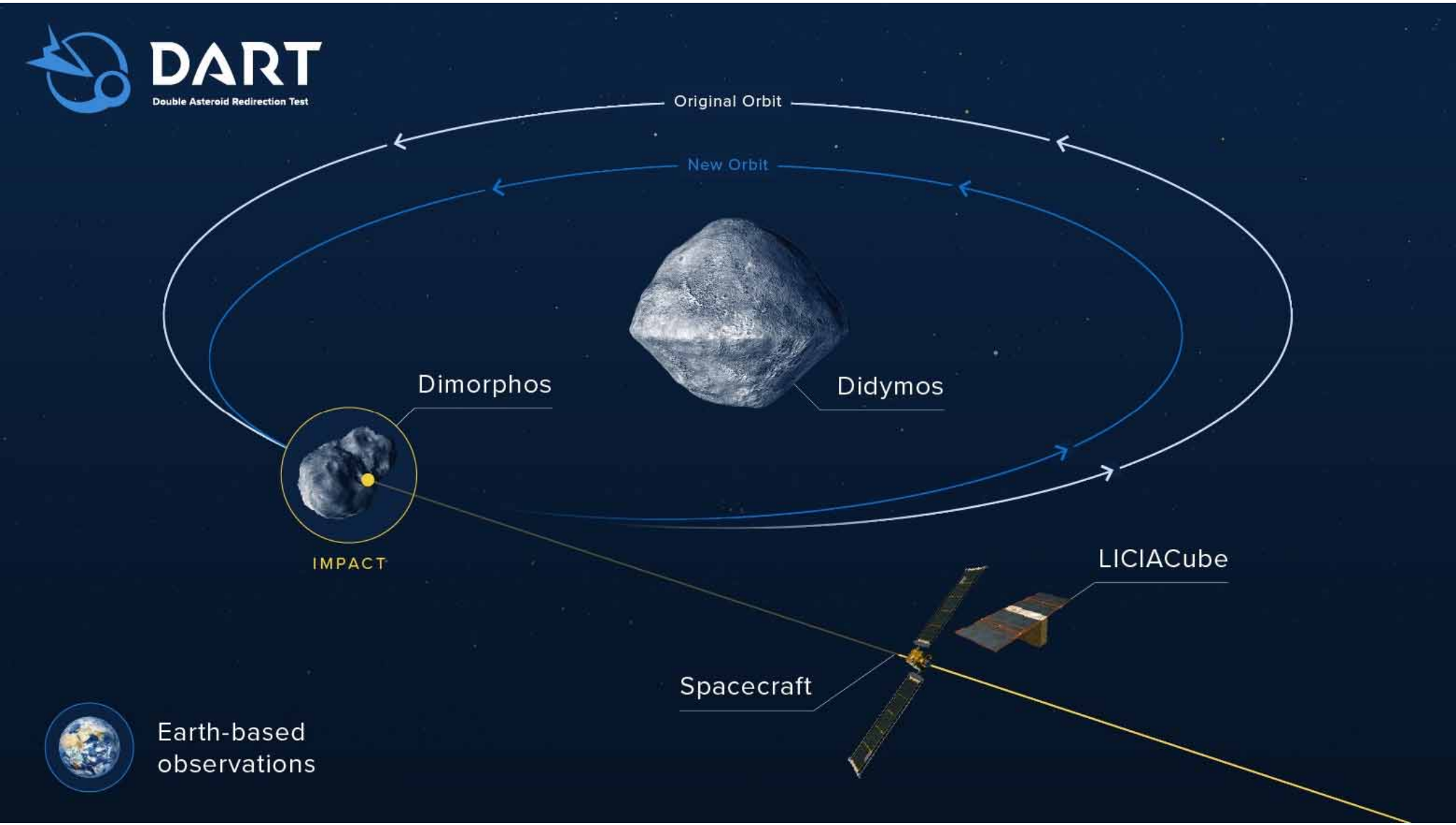
4



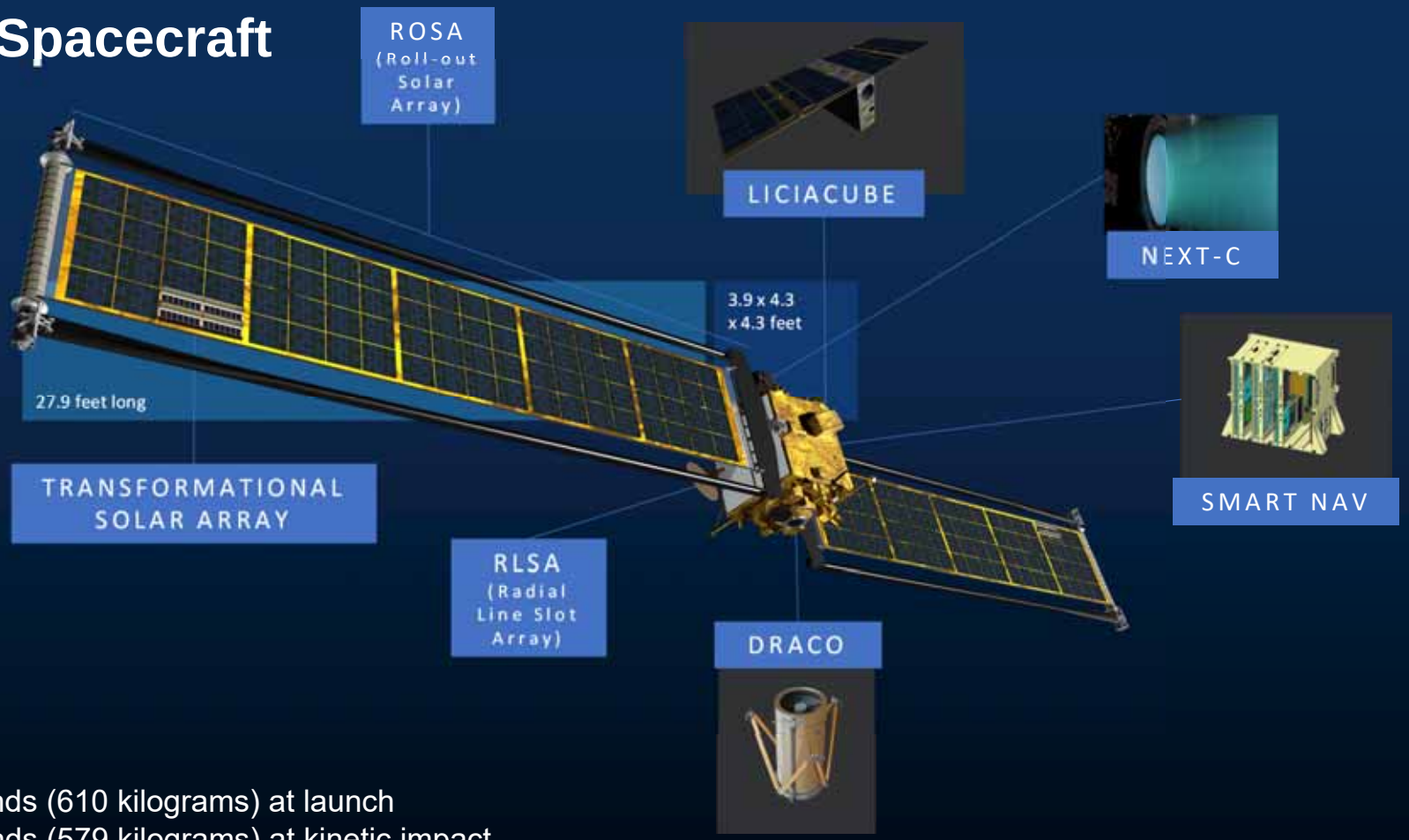
Measure “Beta” and characterize the impact site and dynamics

Beta *= the momentum enhancement factor*

Defining the Mission’s Planetary Defense Investigation


DART
Double Asteroid Redirection Test
Original Orbit
New Orbit
Dimorphos
Didymos
IMPACT
LICIACube
Spacecraft
Earth-based
observations

DART Spacecraft

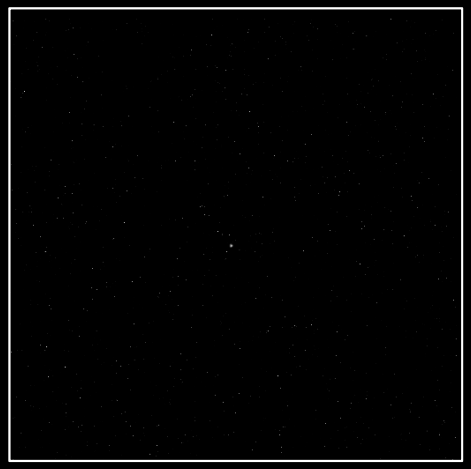


Weight:
~1,345 pounds (610 kilograms) at launch
~1,276 pounds (579 kilograms) at kinetic impact

DART Operations: DRACO

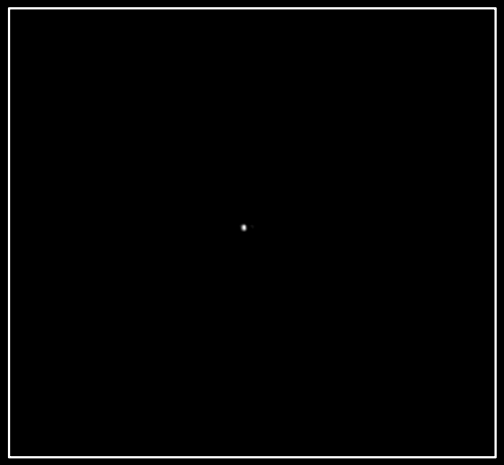
10 Dec 2021, Messier 38

Autonomously Navigating to Asteroid Impact



90,000 kilometers
Didymos – 1 pixel
Started SMARTNav autonomous navigation

4 hours



25,000 kilometers
Didymos – 8 pixel
Dimorphos – 2 pixel
Started tracking Dimorphos

68 minutes

920 kilometers
Didymos – 180 pixel
Dimorphos – 38 pixel
Final downlinked images to contain all of Didymos

2.5 minutes

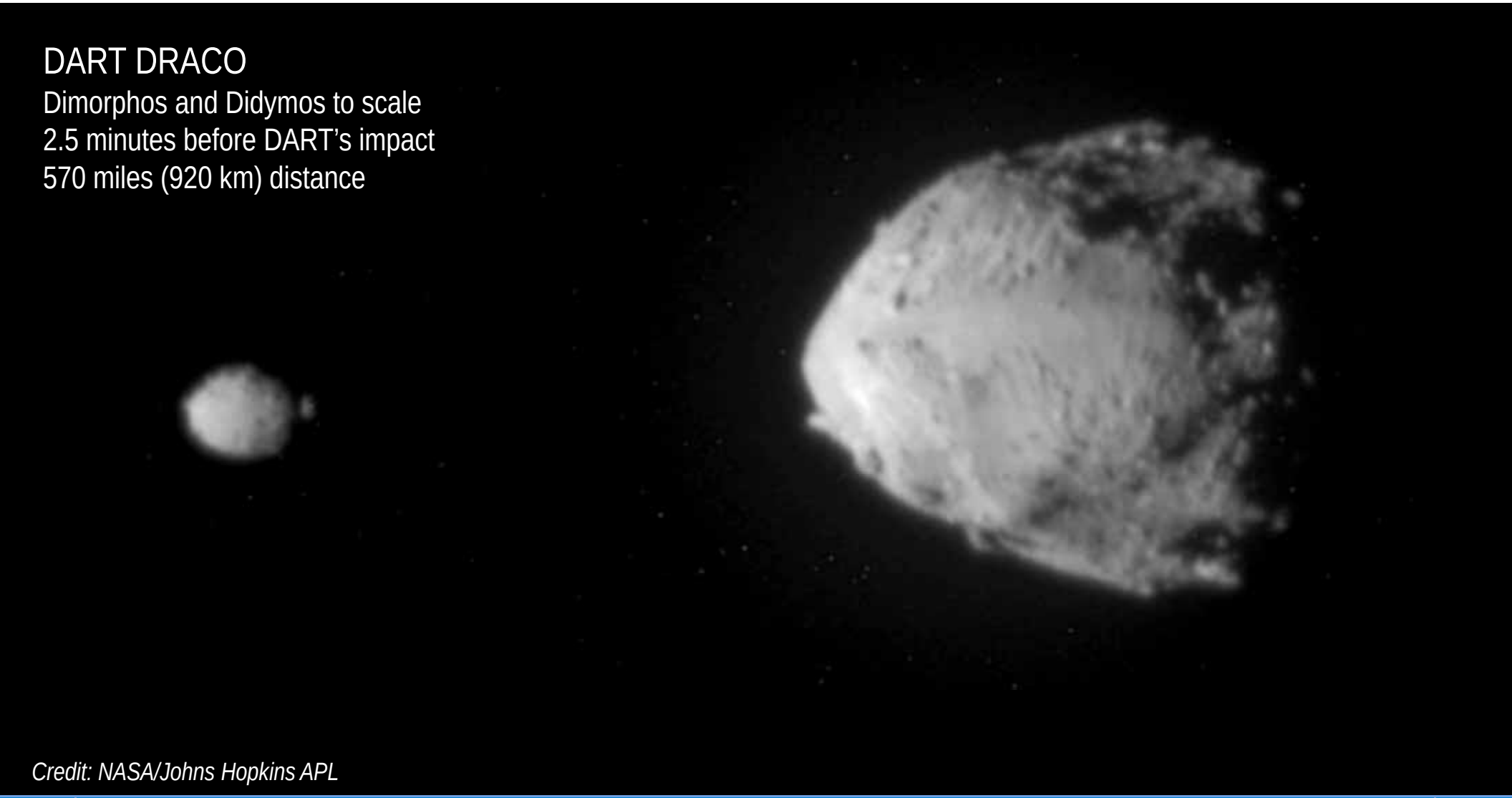
12 kilometers
Dimorphos image
31 meters across
Penultimate Image

2 second


Sept 26 7:10 - 7:15 pm EST
DRACO images streamed to Earth from 7 million miles away
10x speed
Credit: NASA/Johns Hopkins APL

DART DRACO

Dimorphos and Didymos to scale
2.5 minutes before DART's impact
570 miles (920 km) distance



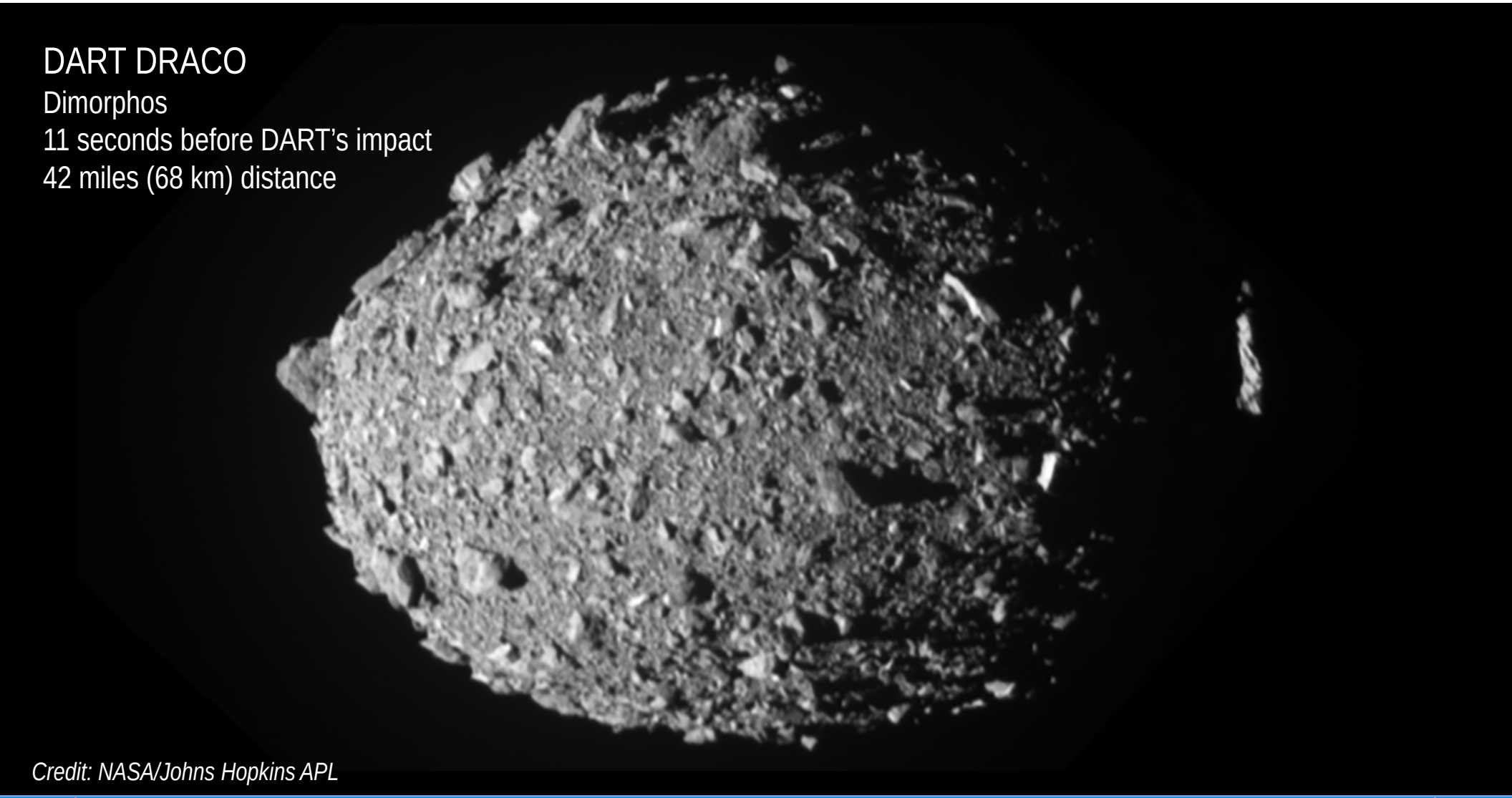
Credit: NASA/Johns Hopkins APL

DART DRACO

Dimorphos

11 seconds before DART's impact

42 miles (68 km) distance

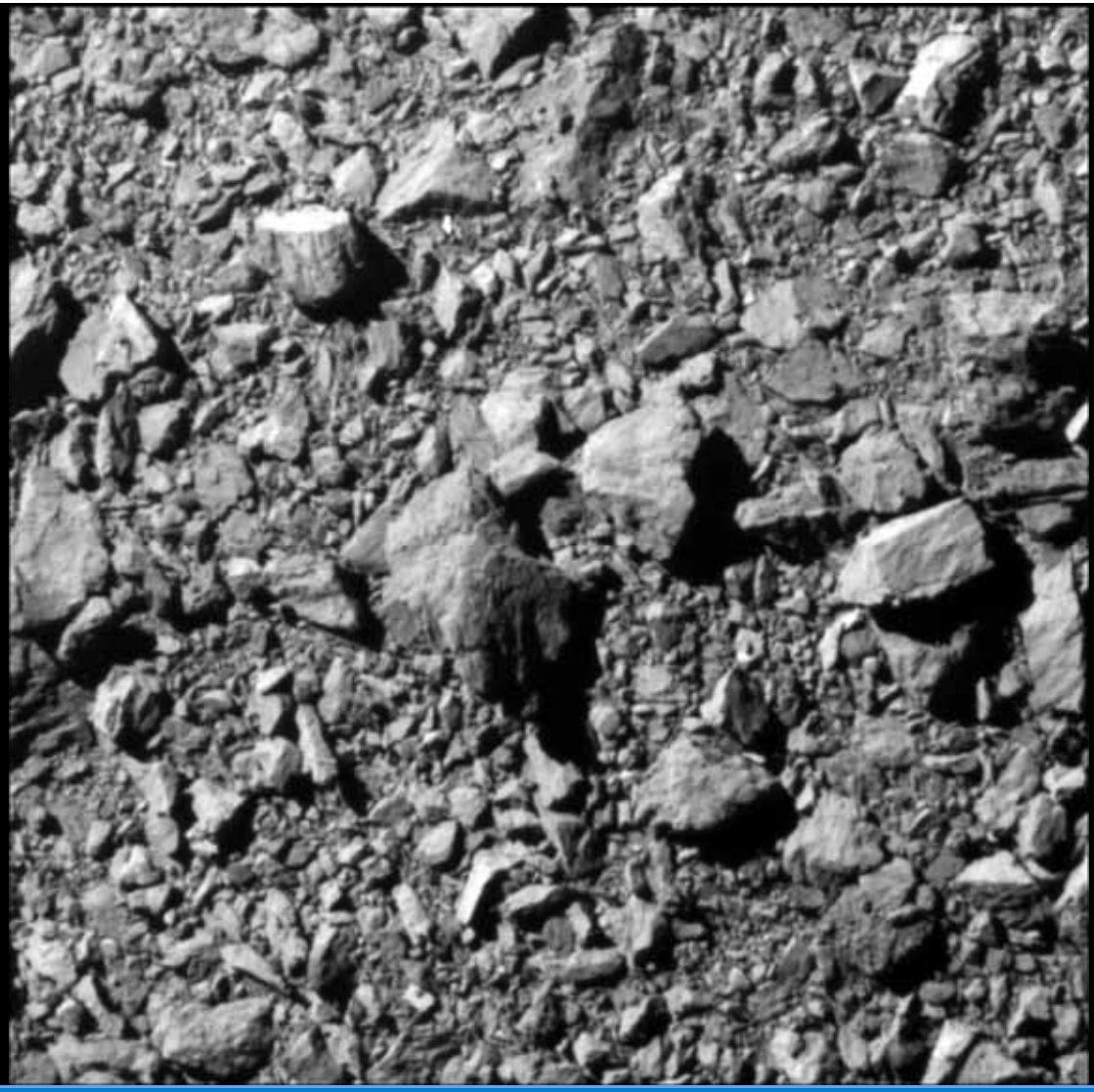


Credit: NASA/Johns Hopkins APL

DART DRACO

Dimorphos
2 seconds before DART's impact
7 miles (12 km) distance

Image is ~100 feet (31 m) across



Credit: NASA/Johns Hopkins APL

Planetary Defense – International Cooperation for an International Issue

AIDA

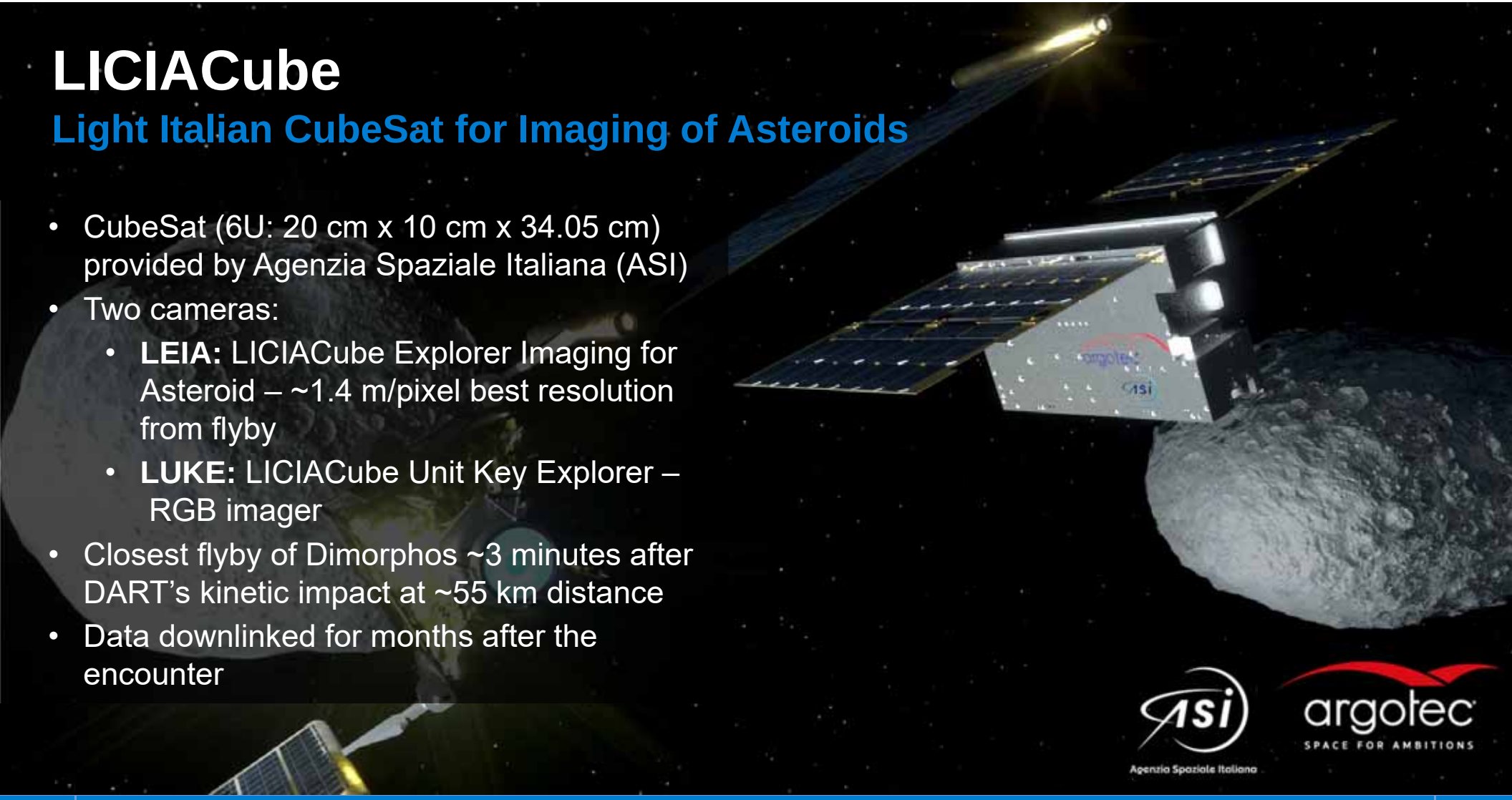
Intercept: *2022*
NASA

Rendezvous: *2026*
ESA

LICIACube

Light Italian CubeSat for Imaging of Asteroids

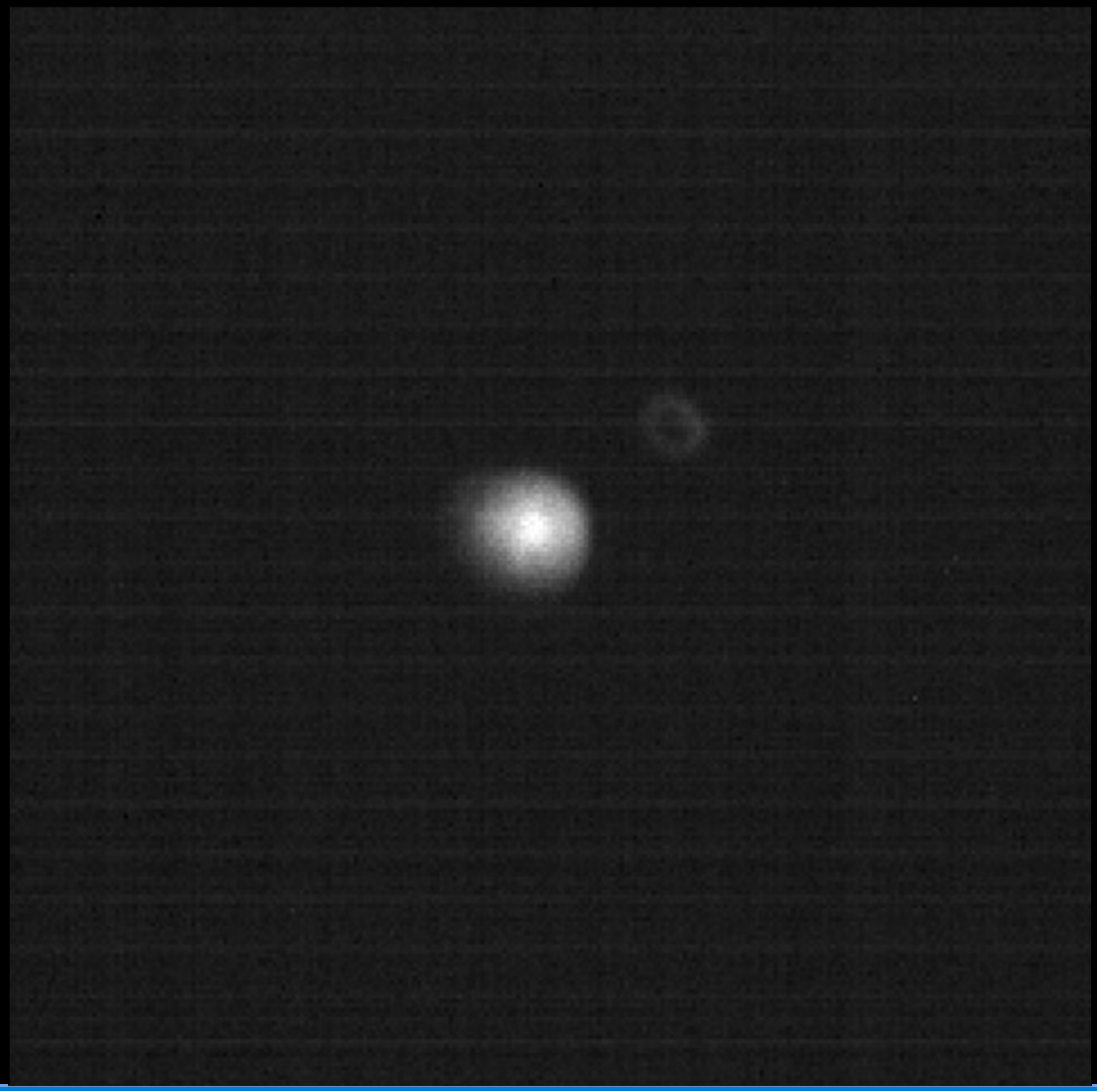
- CubeSat (6U: 20 cm x 10 cm x 34.05 cm) provided by Agenzia Spaziale Italiana (ASI)
- Two cameras:
  - **LEIA:** LICIACube Explorer Imaging for Asteroid – ~1.4 m/pixel best resolution from flyby
  - **LUKE:** LICIACube Unit Key Explorer – RGB imager
- Closest flyby of Dimorphos ~3 minutes after DART's kinetic impact at ~55 km distance
- Data downlinked for months after the encounter



LICIACube LEIA

Two images taken 6 seconds apart showing Dimorphos' brightness before and after impact

(LICIACube-Dimorphos distance = 1020 km)



Credit: ASI/ NASA

LICIACube LUKE

Roughly 3 minutes after DART's impact

(LICIACube-Dimorphos distance = 54 km)

Credit: ASI/ NASA

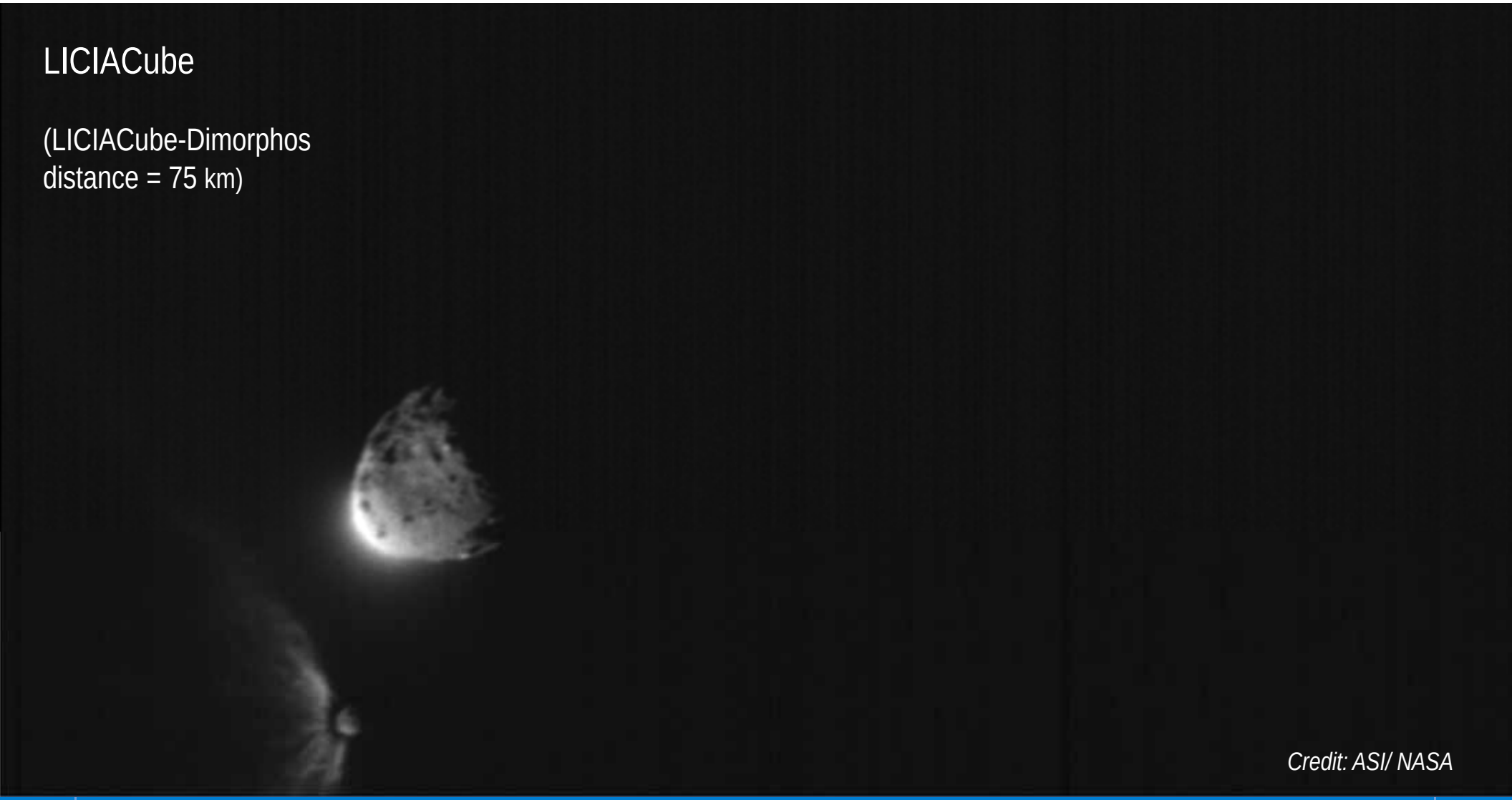
LICIACube

(LICIACube-Dimorphos distance = 76 km)

Credit: ASI/ NASA

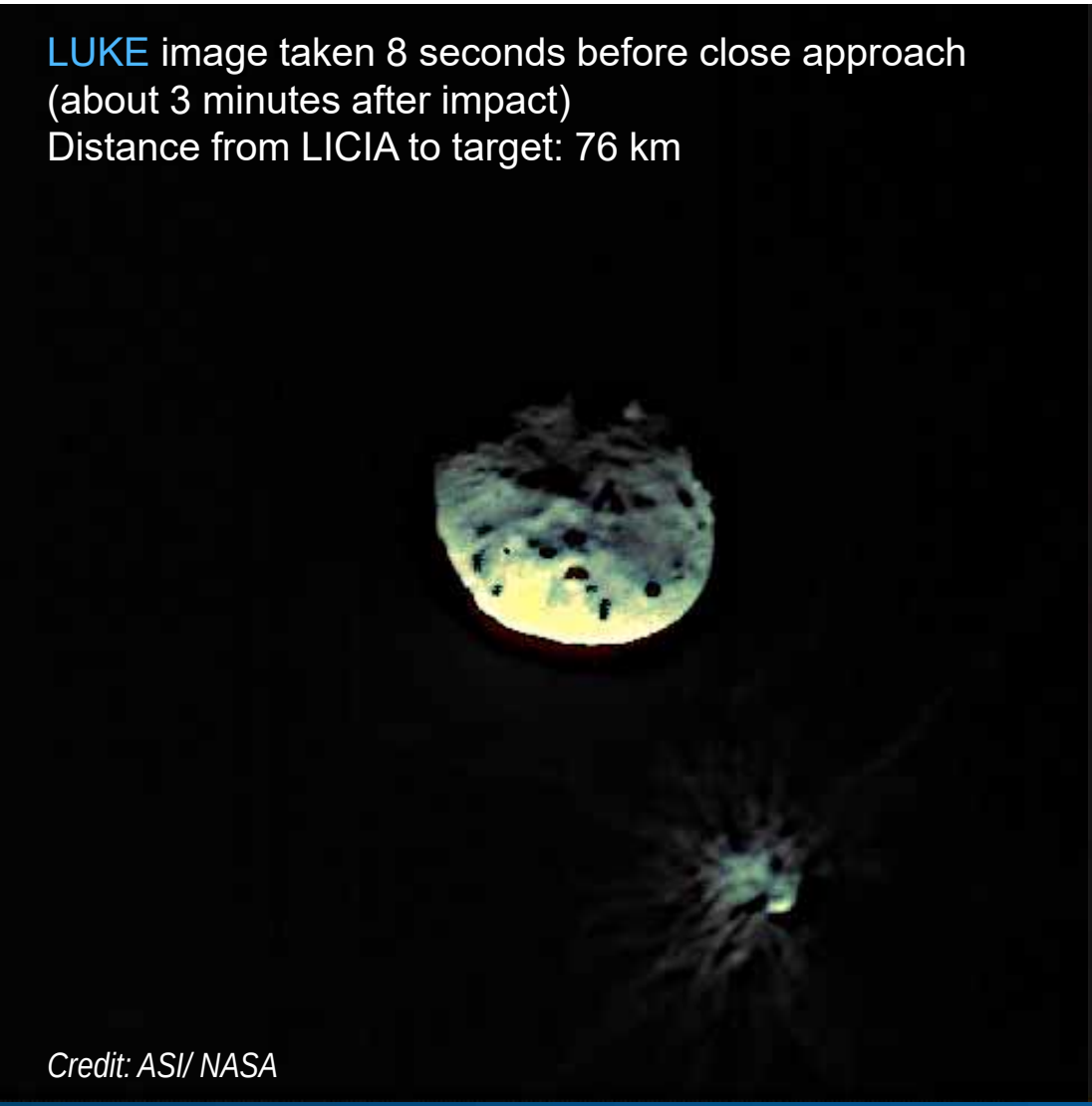
LICIACube

(LICIACube-Dimorphos distance = 75 km)



Credit: ASI/ NASA

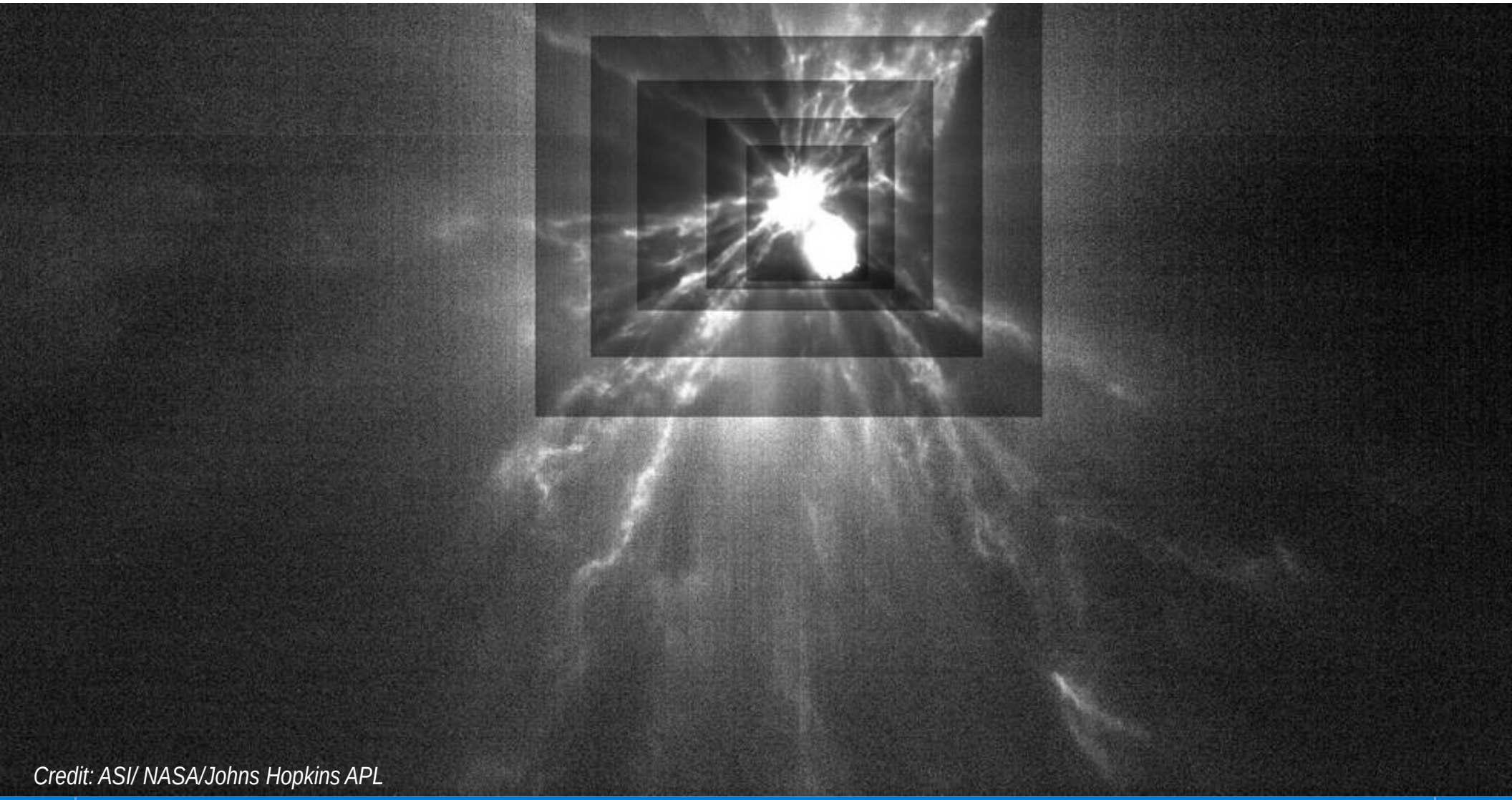
LUKE image taken 8 seconds before close approach
(about 3 minutes after impact)
Distance from LICIA to target: 76 km



Credit: ASI/ NASA

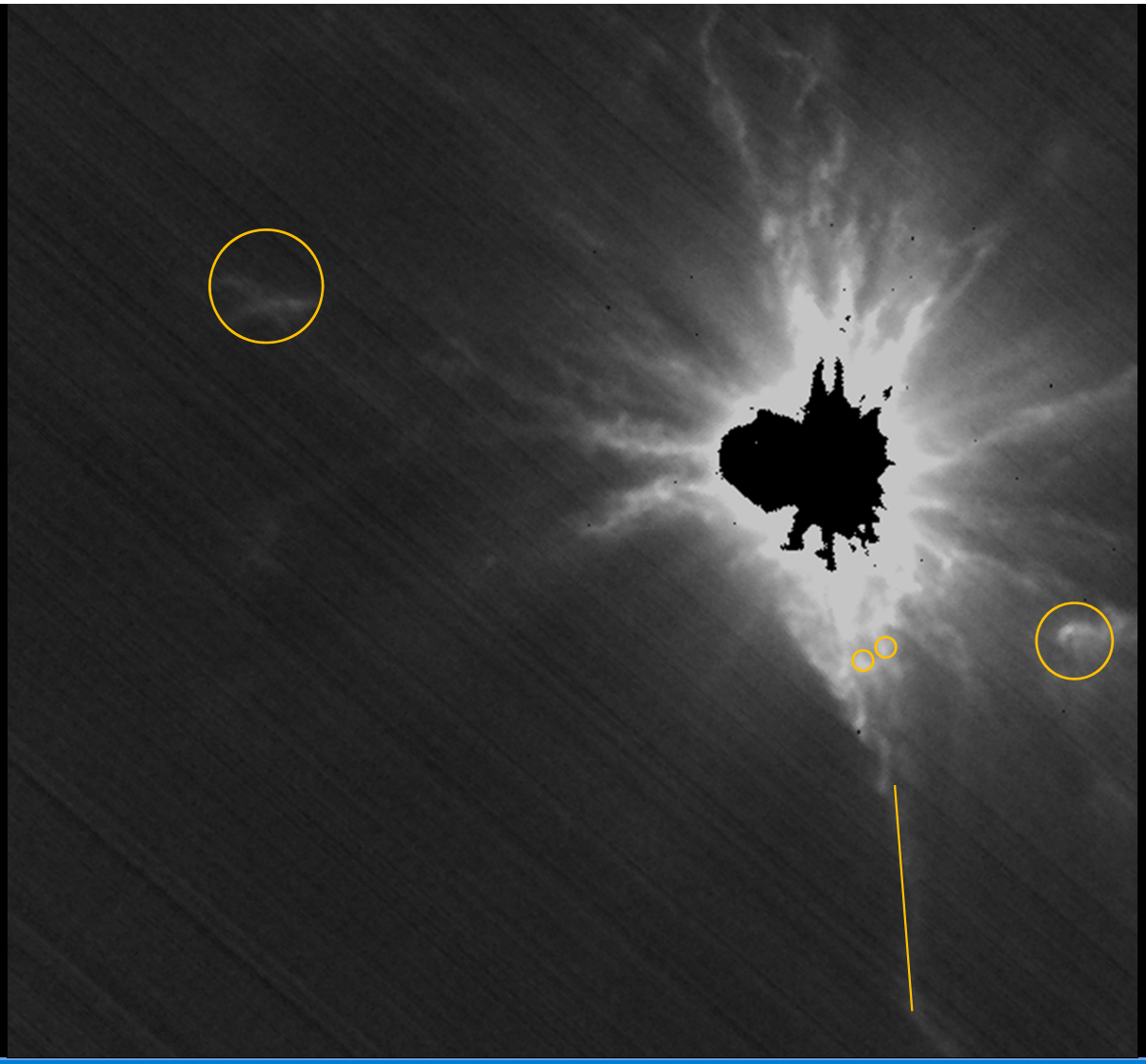
LUKE image taken 7 seconds after close approach
(about 3 minutes after impact)
Distance from LICIA to target: 71 km

Credit: ASI/ NASA



Credit: ASI/ NASA/Johns Hopkins APL

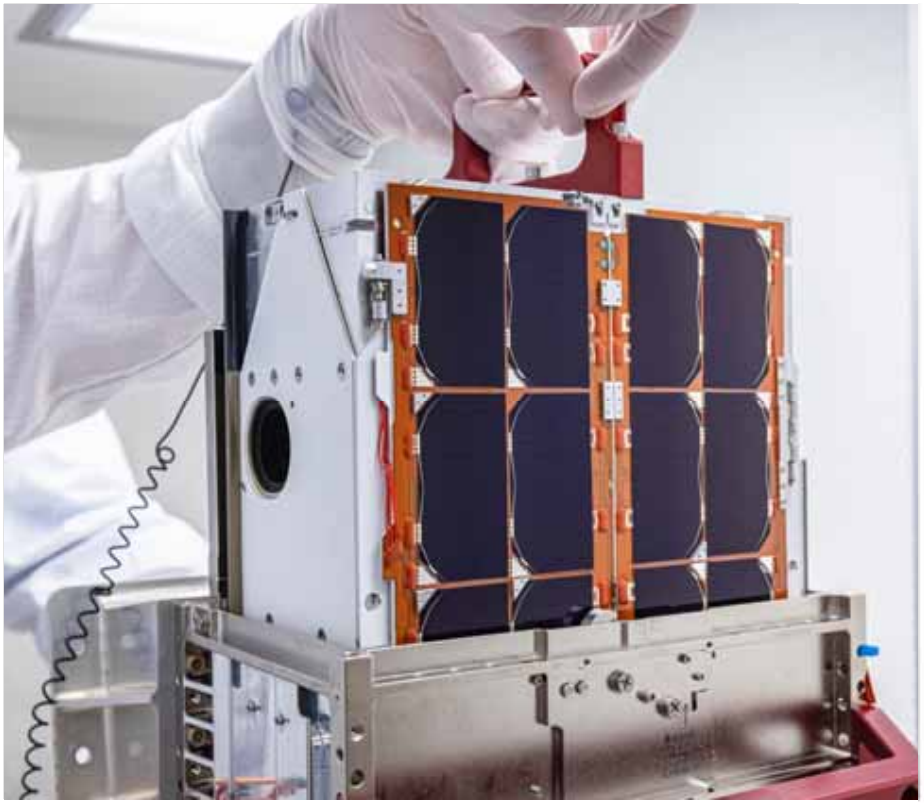
LUKE image taken about 2 minutes after impact
Distance from LICIA to target: 303 km

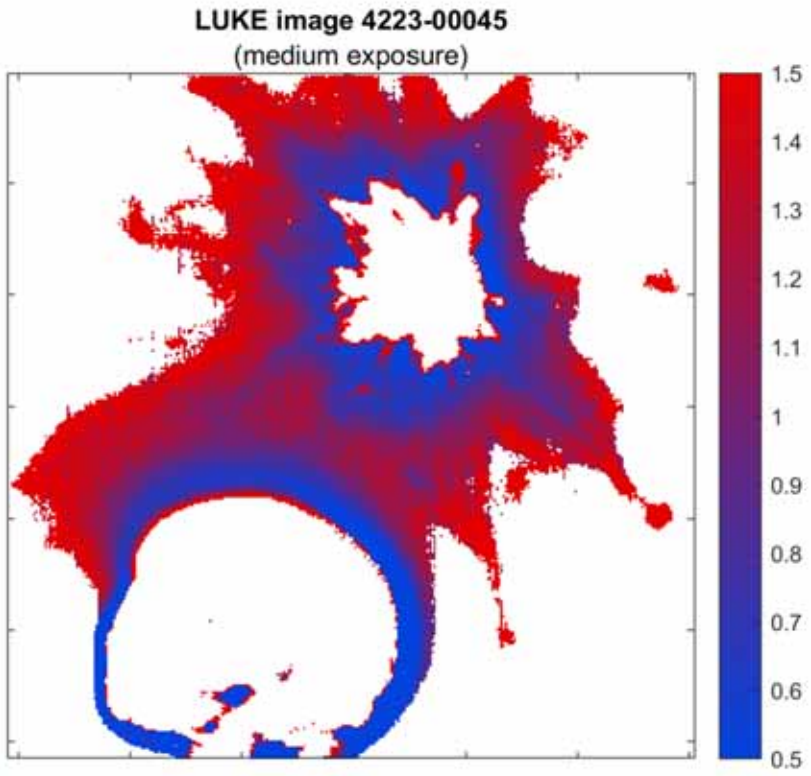


Credit: ASI/ NASA

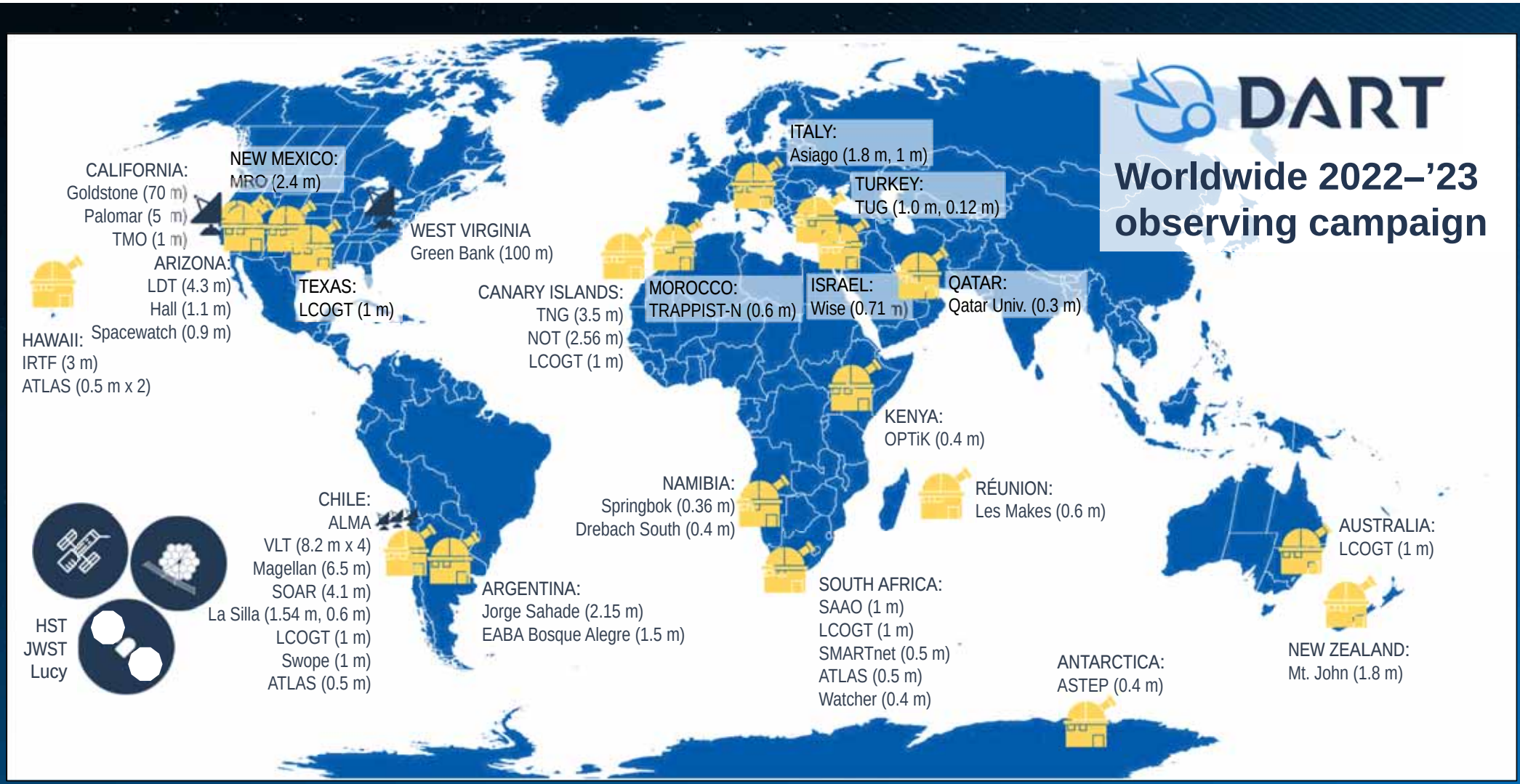
Investigating the plume characteristics with colors

(from monochromatic to red vs. blue filters ratio)





Credit: ASI/ NASA


DART
Worldwide 2022–'23
observing campaign
CALIFORNIA:
Goldstone (70 m)
Palomar (5 m)
TMO (1 m)
NEW MEXICO:
MRO (2.4 m)
ARIZONA:
LDT (4.3 m)
Hall (1.1 m)
Spacewatch (0.9 m)
TEXAS:
LCOGT (1 m)
WEST VIRGINIA
Green Bank (100 m)
HAWAII:
IRTF (3 m)
ATLAS (0.5 m x 2)
CANARY ISLANDS:
TNG (3.5 m)
NOT (2.56 m)
LCOGT (1 m)
ITALY:
Asiago (1.8 m, 1 m)
TURKEY:
TUG (1.0 m, 0.12 m)
MOROCCO:
TRAPPIST-N (0.6 m)
ISRAEL:
Wise (0.71 m)
QATAR:
Qatar Univ. (0.3 m)
KENYA:
OPTiK (0.4 m)
NAMIBIA:
Springbok (0.36 m)
Drebach South (0.4 m)
RÉUNION:
Les Makes (0.6 m)
CHILE:
ALMA
VLT (8.2 m x 4)
Magellan (6.5 m)
SOAR (4.1 m)
La Silla (1.54 m, 0.6 m)
LCOGT (1 m)
Swope (1 m)
ATLAS (0.5 m)
ARGENTINA:
Jorge Sahade (2.15 m)
EABA Bosque Alegre (1.5 m)
SOUTH AFRICA:
SAAO (1 m)
LCOGT (1 m)
SMARTnet (0.5 m)
ATLAS (0.5 m)
Watcher (0.4 m)
AUSTRALIA:
LCOGT (1 m)
NEW ZEALAND:
Mt. John (1.8 m)
ANTARCTICA:
ASTEP (0.4 m)
HST
JWST
Lucy

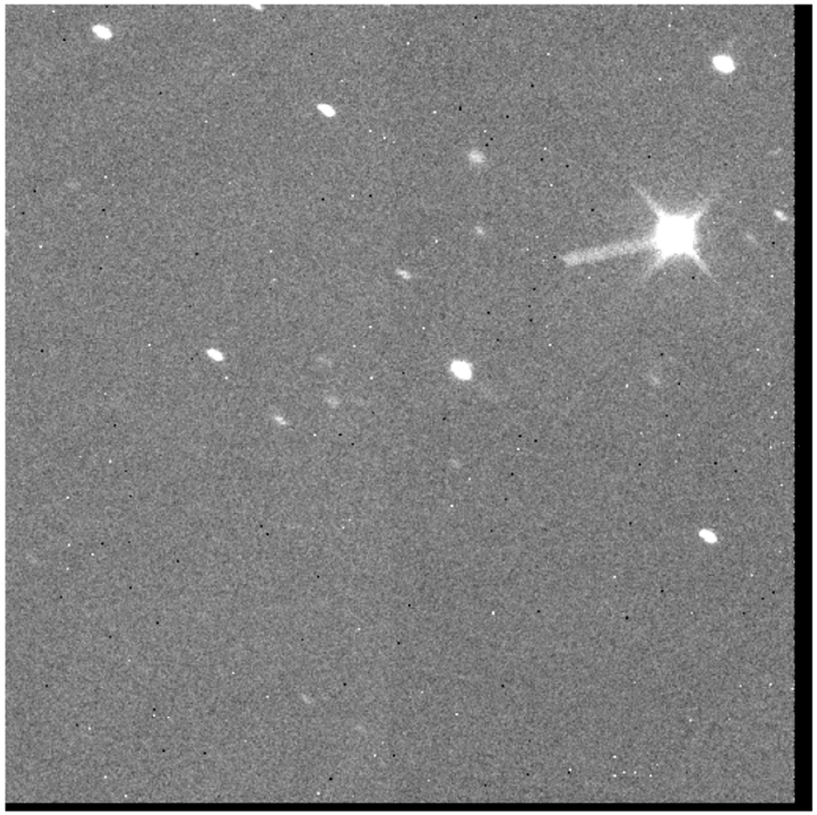
September 26
23:26 UTC
(12 min. post-impact)

23:29 UTC
(15 min. post-impact)

Credit: Tim Lister, Joseph Chatelain, Rachel Street, Edward Gomez, Joseph Farah / Las Cumbres Observatory.

LCOGT 1 meter Telescope at SAAO South Africa

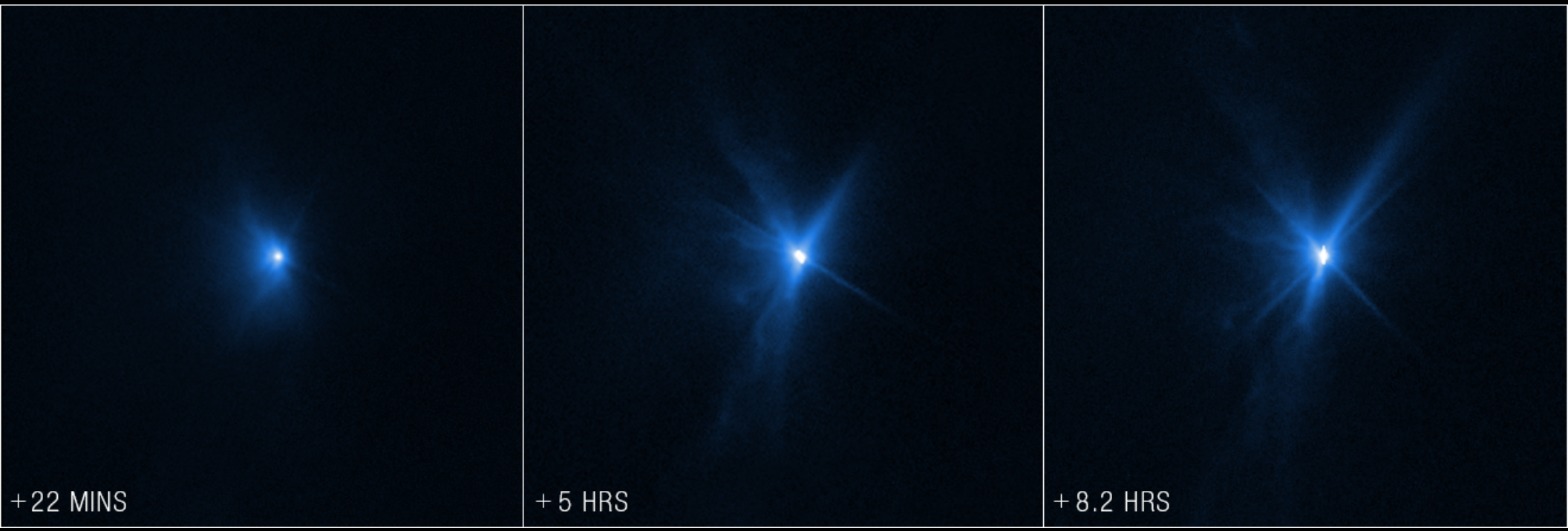
UT Date: 09/26/2022 11:10:50 PM (1 of 50)



September 27, 2022
~5 hours post-impact

Credit: Science: NASA, ESA, CSA, Jian-Yang Li (PSI), Cristina Thomas (Northern Arizona University), Ian Wong (NASA-GSFC); image processing: Joseph DePasquale (STScI), Alyssa Pagan (STScI)

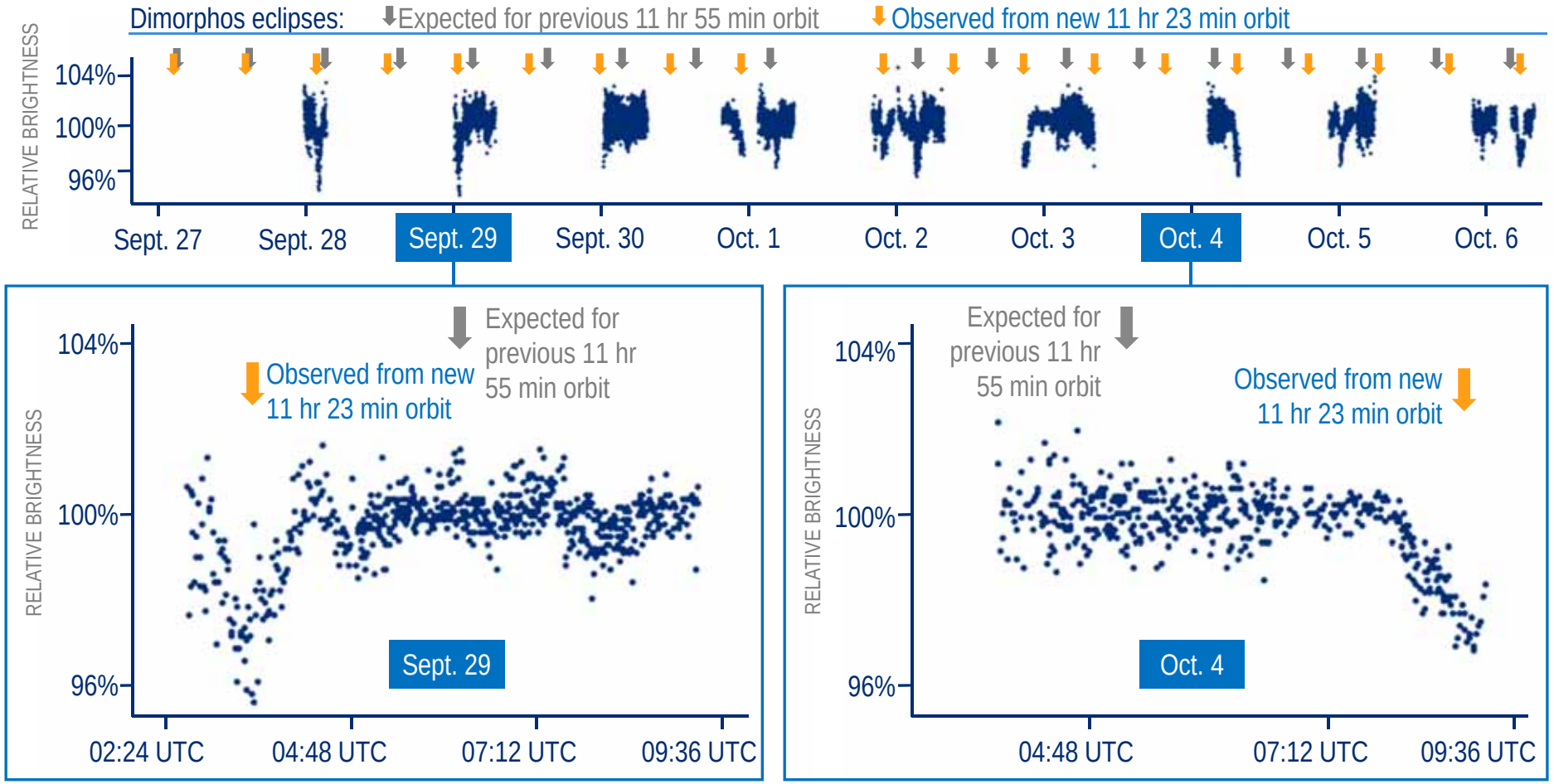
Hubble Space Telescope



Credit: Science: NASA, ESA, Jian-Yang Li (PSI); image processing: Alyssa Pagan (STScI)

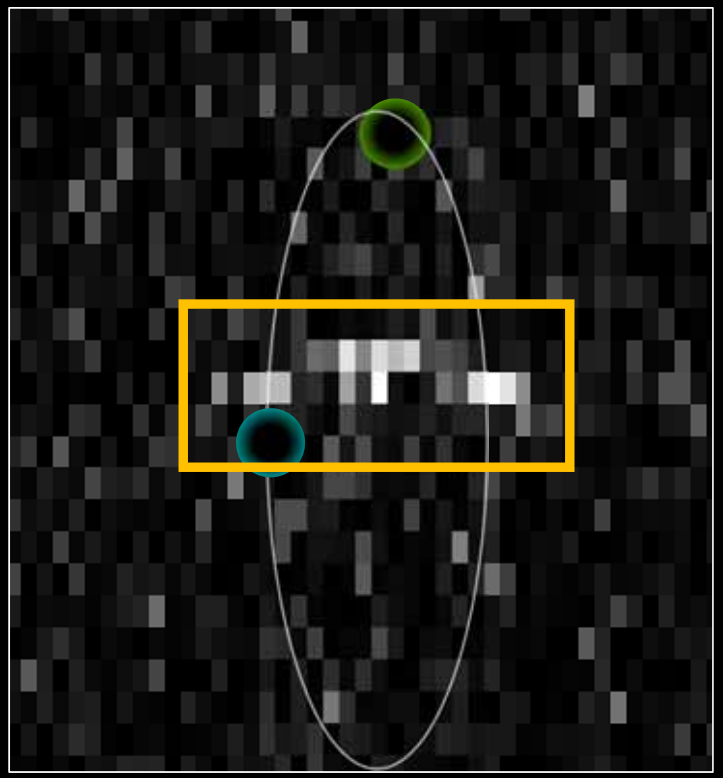

November 30, 2022
Magdalena Ridge Observatory
New Mexico, USA
64 days post-impact
Credit: MRO/ NM Tech

Observations after DART impact show orbit change

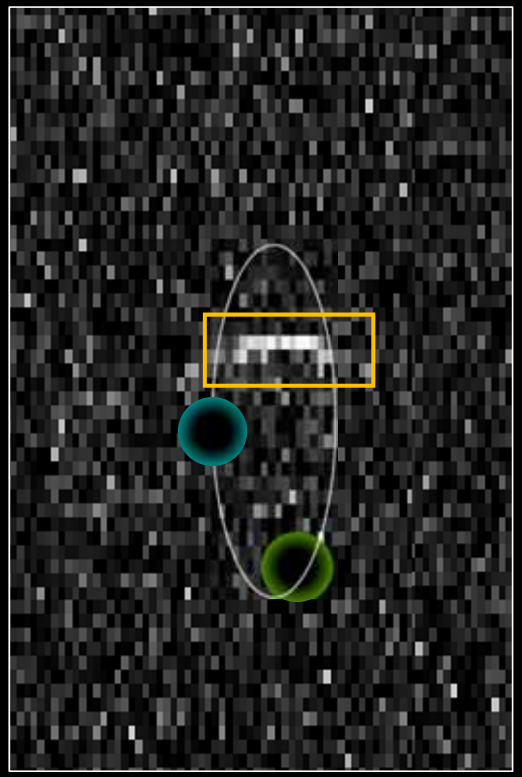


Credit: NASA/Johns Hopkins APL/Astronomical Institute of the Academy of Sciences of the Czech Republic/Lowell Observatory/JPL/Las Cumbres Observatory/Las Campanas Observatory/European Southern Observatory Danish (1.54-m) telescope/University of Edinburgh/The Open University/ Universidad Católica de la Santísima Concepción/Seoul National Observatory/Universidad de Antofagasta/Universität Hamburg/Northern Arizona University

Radar images detect Didymos and Dimorphos



2022 Oct 04 11:55:39 UTC



2022 Oct 09 10:56:47 UTC

- Didymos
- Dimorphos
- Expected Dimorphos From 11 hr. 55 min. orbit
- Dimorphos orbit

Credit: NASA/Johns Hopkins APL/JPL/NASA JPL Goldstone Planetary Radar/National Science Foundation's Green Bank Observatory

October 9

Radar images detect Didymos and Dimorphos

Credit: NASA/Johns Hopkins APL/JPL/NASA JPL Goldstone Planetary Radar/National Science Foundation's Green Bank Observatory


NO EJECTA
Momentum Enhancement
Factor = 1
SOME EJECTA
DART EJECTA
Momentum Enhancement
Factor ~3.6
LOTS OF EJECTA

Momentum Transfer Enhancement Factor β

- The DART impact shortened orbital period of Dimorphos around Didymos by 33 $\pm$ 1 min
- This period change implied an instantaneous reduction of orbital speed Δv_T by 2.70 $\pm$ 0.1 mm s^{-1}, as determined by full two-body dynamical simulations
- This Δv_T implied an enhanced transfer of momentum due to recoil from ejecta streams

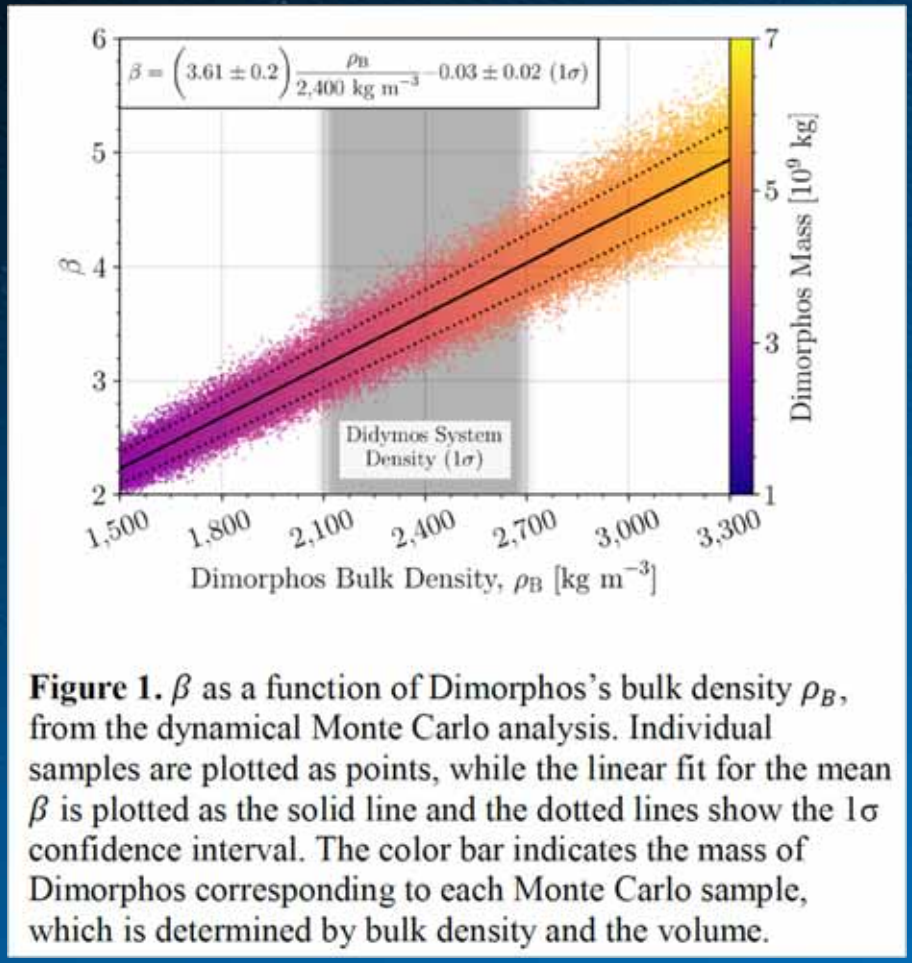
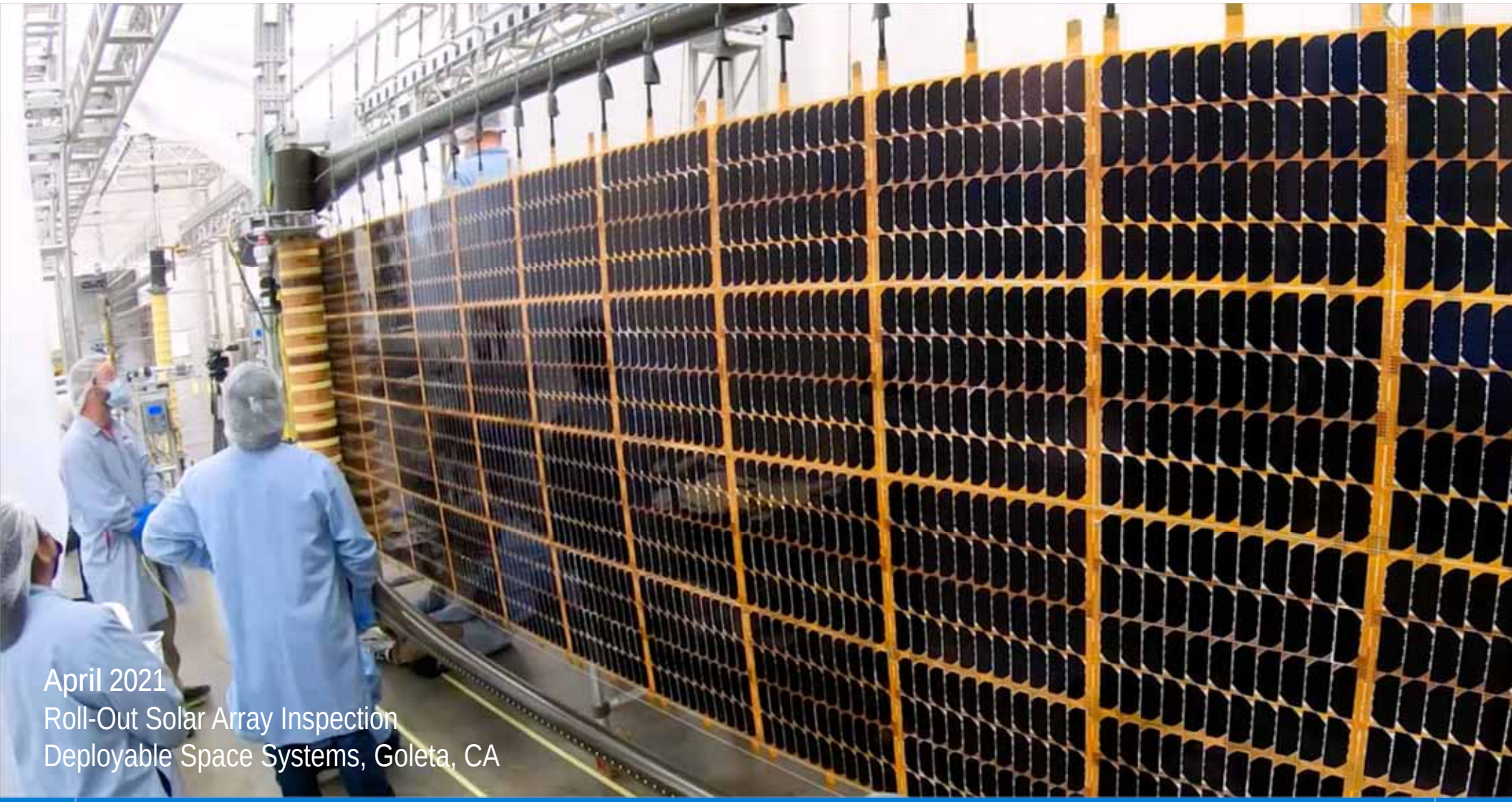
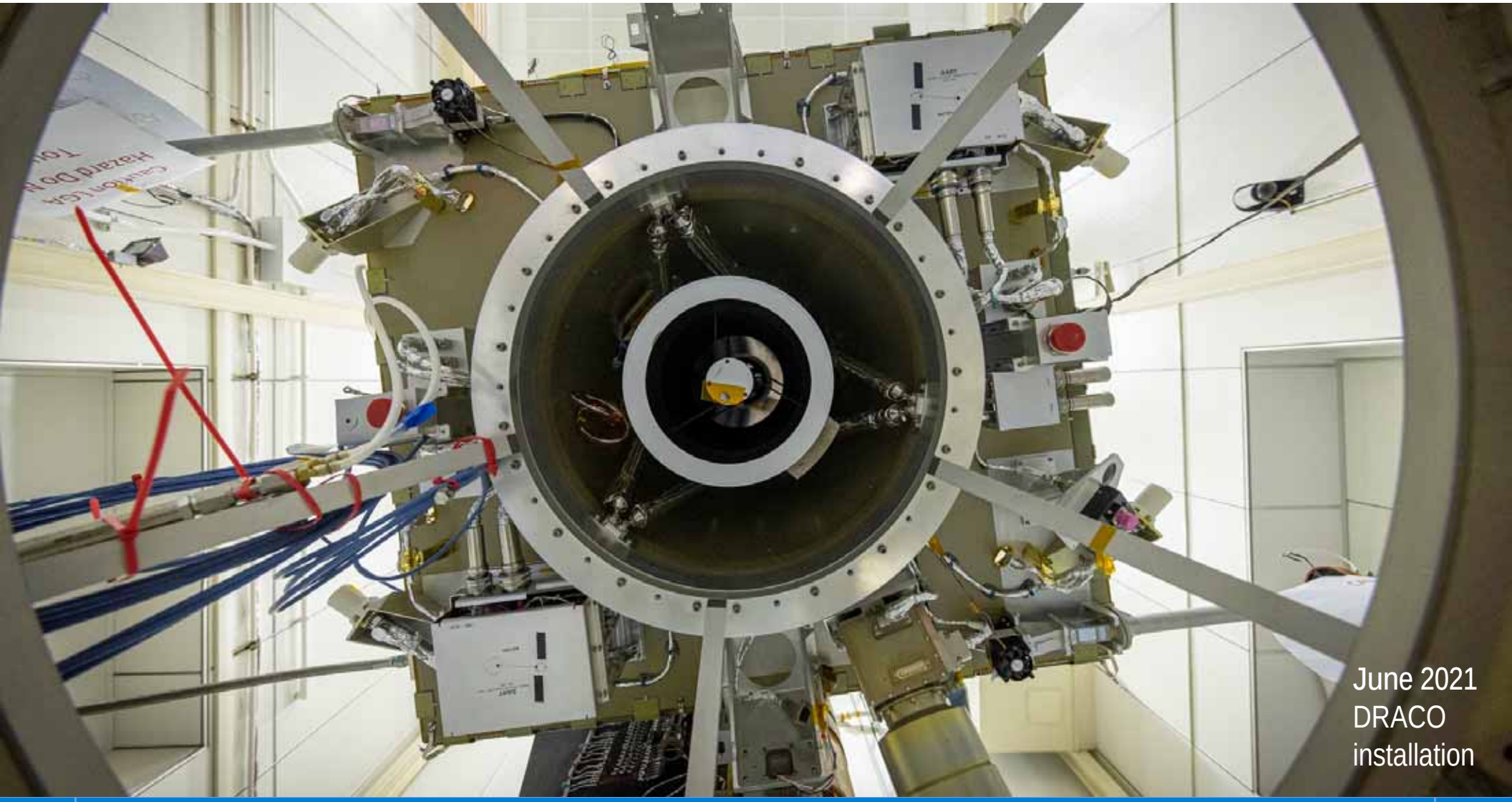


Figure 1. β as a function of Dimorphos's bulk density ρ_B, from the dynamical Monte Carlo analysis. Individual samples are plotted as points, while the linear fit for the mean β is plotted as the solid line and the dotted lines show the 1σ confidence interval. The color bar indicates the mass of Dimorphos corresponding to each Monte Carlo sample, which is determined by bulk density and the volume.


Jan 2021
Thermal Vacuum
Testing



April 2021
Roll-Out Solar Array Inspection
Deployable Space Systems, Goleta, CA



June 2021
DRACO
installation

Sept. 2021
LICIACube
Integration

Bill Ingalls/NASA